

SITE FIDELITY AND LOCAL MOVEMENTS OF MIGRATING WESTERN SANDPIPERS ON THE FRASER RIVER ESTUARY

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ABSTRACT.—The Western Sandpiper (*Calidris mauri*) is the most numerous shorebird on the Pacific coast of North America during spring migration. Twenty-six sandpipers carrying miniature radio transmitters on northward migration across the Fraser River delta, British Columbia, remained on or near to the section of beach where they were first detected through their entire stay. They traveled about 4–6 km each day, following the tide up and down the beach. Although some Western Sandpipers were present on all beaches of the delta, our results suggest that individuals do not roam widely once they settle. The widespread distribution of sandpipers in mud, marsh, and sand habitats suggests that all regions of the Fraser River delta are required to support the large number of Western Sandpipers during spring migration. Received 19 February 2002, accepted 6 August 2002.

Conservation programs aimed at protecting migrant shorebirds require information on how species use habitats. Migrating birds might choose among habitats at stopover sites by trading off energetic requirements for continued migration against competitors and avoidance of predators (Metcalf and Furness 1984, Lindström 1990, Bednekoff and Houston 1994, Clark and Butler 1999, Moore and Aborn 2000, Ydenberg et al. 2002). There are many interacting factors in these decisions, including the fuel loads carried by birds (van Gils and Piersma 1999, Moore and Aborn 2000), their escape maneuverability and the danger from avian predators (Burns and Ydenberg 2002, Ydenberg et al. 2002), the suitability of atmospheric conditions for continued migration, and the position of the individual on the migration relative to other individuals (Butler et al. 1997, Clark and Butler 1999). Moving to a new location might be risky in areas with predatory falcons. Shorebirds also might select particular places to feed that reflect differential prey selection in response to bill and gut morphologies (Sutherland et al. 2000). In either case, there is a paucity of empirical data on the daily movements of individual shorebirds during migration to test these ideas.

The Fraser River delta, British Columbia,

supports an abundance of migrant shorebirds, most notably the Western Sandpiper (*Calidris mauri*). The number of sandpipers arriving on the delta increases quickly in late April to a peak number between 100,000 and 500,000 individuals in early May, after which numbers quickly decline, and the migration is largely over by about 10 May (Butler 1994). The time spent by individuals at stopover sites has been estimated for this species (Iverson et al. 1996, Warnock and Bishop 1998), but daily use of habitats by individuals while on migration is unknown. In this paper, we describe how individual Western Sandpipers use habitats on the Fraser River delta during spring migration.

STUDY AREA AND METHODS

Study site.—We conducted field work on the Fraser River delta, British Columbia (49° 10' N, 123° 00' W), during spring migration in 1992 and 1995. We examined how individual sandpipers were distributed on the delta during the periods 17 April to 6 May 1992 and 26 April to 14 May 1995. During very low tides, the Fraser River delta has about 22,000 ha of exposed mud and sand beach, about 11,000 ha along the southern shore of the delta (Boundary Bay), 6,000 ha along the southwestern shore (Roberts Bank), and about 5,000 ha along the western shore (Sturgeon Bank; Fig. 1). Boundary Bay and Sturgeon Bank consist of mixed silt and sand whereas Roberts Bank is mostly silt and sand to the south of an industrial jetty and silt and clay to the north. Dense eelgrass beds cover Boundary Bay and the southern portion of Roberts Bank south of the industrial port jetty below about the 1.5- to 2.0-m tide. Eleven sections of the delta (herein “beach section”) were designated by nearby road and geographical features (Fig. 1). The width of each beach section at high tide was about 2–6 km.

Tracking.—We studied how Western Sandpipers

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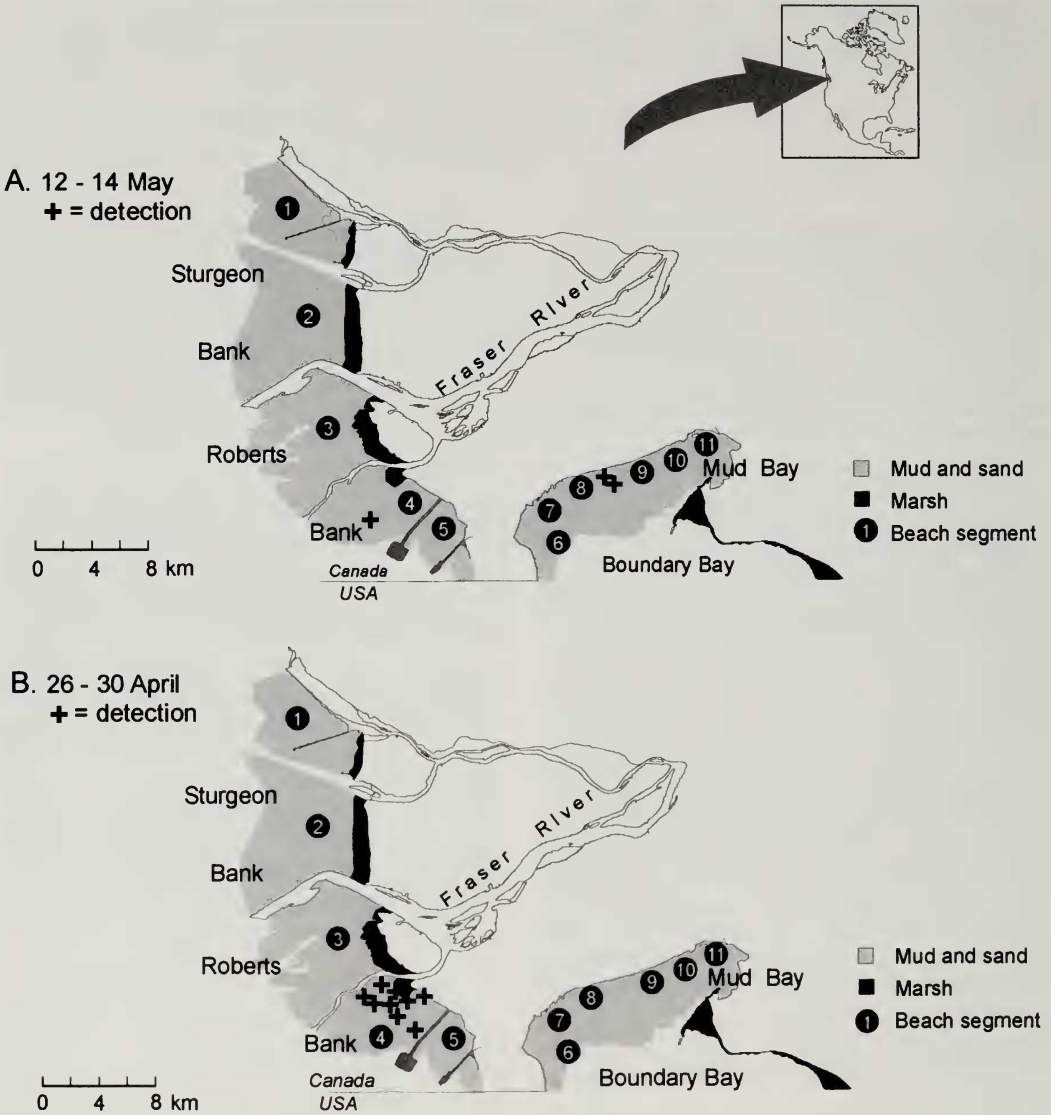


FIG. 1. Detection locations of two radio-marked Western Sandpipers on the Fraser River delta, British Columbia, during 1995.

used the delta by aerial tracking (Iverson et al. 1996) during 1992 (beach sections 1–11) and by ground tracking (Shepherd 2001) of individuals carrying miniature radio transmitters glued to their rump feather tracts (Warnock and Warnock 1993) during 1995 (beach sections 4–11). In 1992, a 0.8-g transmitter (Holohil Systems) was attached to each of four sandpipers caught in California and 11 sandpipers caught on Roberts Bank on the Fraser River delta. The presence of sandpipers carrying transmitters was detected from a Cessna 172 aircraft flown on 18 days for 1.0–1.5 h at about 150 m over the entire intertidal portion of the delta when tides were about 3 m high. Two days

of incomplete coverage by aircraft over the delta were excluded from the analysis. We also discarded data from seven transmitters that were heard only once or likely fell off the bird because they were heard repeatedly from one site after the migration was nearly over. We attached a Yagi antenna to the wing strut of the aircraft and used it in connection with an Advanced Telemetry Systems® receiver to detect transmitter frequencies. On 3 May 1992, we flew during a low tide to locate and compare individual movements over the entire exposed beach. We assumed that a radio-marked sandpiper was on the beach below the airplane where the signal was strongest. One observer recorded on a

TABLE 1. Distribution of Western Sandpipers along exposed beach sections of the Fraser River delta, British Columbia, during aerial surveys on 18 days between 17 April and 6 May 1992.

Beach section ^a	Area (%)	Total	Density (birds/ha)
1	105 (4.2)	59,920	571
2	375 (14.9)	42,950	115
3	353 (14.0)	64,950	183
4	244 (9.7)	414,500	1698
5	121 (4.8)	81,620	675
6	36 (1.4)	10,800	300
7	238 (9.4)	55,700	234
8	243 (9.6)	63,920	263
9	291 (11.6)	50,970	175
10	283 (11.2)	85,650	303
11	231 (9.2)	92,900	402
Total	2520 (100.0)	1,023,880	

^a Sturgeon Banks includes beaches 1–2, Roberts Bank 3–5, and Boundary Bay 6–11.

map the location of each radio-marked bird and estimated the number of sandpipers present on the 11 beach sections. The mean number of days that the 4 sandpipers fitted with radios in California and the 11 sandpipers radio tagged on Roberts Bank were in residence on the Fraser River delta were identical (2.8 days). Therefore, we assumed there was no handling effects on the behavior of birds caught locally and those caught in California.

To estimate the relative density of shorebirds on various beach sections on the delta, we recorded on a map the number and locations of all shorebirds seen during aerial tracking flights during 1992. Aerial surveys can overlook and underestimate the number of birds in large flocks. We assumed that the bias was consistent among days and regions of the delta and use the data only to compare relative use of beach sections by shorebirds.

During 1995, we spent 19 days tracking signals from 0.9-g radio transmitters (Holohil Systems) attached to six sandpipers in San Francisco Bay, three at Honey Lake, California, and two at Grays Harbor, Washington, that remained on the delta for >1 tidal cycle. We tracked sandpipers daily, within 3 h of day-

time high and low tides. We examined site fidelity between tidal cycles using detections from these six individuals, which were located hourly between high and low tides. We located sandpipers from 25 telemetry stations along a dike near the high tide line of Boundary Bay and Roberts Bank (covering beach sections 4–11; Fig. 1) with a dual-Yagi van mast telemetry system (Warnock and Takekawa 1995). Two compass bearings were taken from consecutive telemetry stations for all signals. We used these data to triangulate the exact Universal Transverse Mercator (UTM) location for each individual detected on each tracking run. Each location was then plotted on a map of the delta.

RESULTS

Sandpipers used all regions of the delta, but were most numerous on Roberts Bank (beach section 4 in Fig. 1). Over two-fifths of all sandpipers were counted there and they were more dense there than at any other section of beach (Table 1). Most sandpipers carrying radio transmitters were relocated each day on the same beach section. The 1992 aerial surveys detected 15 sandpipers with radios on 53 occasions over 18 days of the migration. Of the 53 detections, 8 were made in Boundary Bay, 42 were made on Roberts Bank and 3 were made on Sturgeon Bank. Of 38 detections on subsequent days following the first detection, 33 (87%) were on the same or adjacent beach section (Table 2). During 1995, we detected 11 individuals on 52 occasions separated by tidal cycles and 41 on subsequent days. Of the 52 detections, 10 were made in Boundary Bay and 42 were made on Roberts Bank. Of 41 detections on subsequent days following the first detection, 33 (80%) were on the same or adjacent beach section; the distance between detections in 1992 and 1995 were not significantly different (Table 2).

On average, each beach section covered about 9% of the entire exposed area and each sandpiper stayed for about 3 days (Iverson et

TABLE 2. Relative movement of 26 radio-marked Western Sandpipers detected two or more times on the Fraser River delta, British Columbia, during spring migration. Values do not include first detection. Beach segments are illustrated in Figure 1.

Year ^a	<i>n</i>	Total number of detections	Same beach	Adjacent beach	Two beaches away	Three beaches away	Four beaches away	Five beaches away
1992	15	38	19	14	3	2	0	0
1995	11	41	24	9	2	0	5	1
Total	26	79	43	23	5	2	5	1

^a Difference between years of the number detected on same, 1, 2, and >2 beaches away was not significant ($\chi^2 = 2.3$, $df = 2$, $P = 0.34$).

al. 1996). Thus, the probability of a sandpiper randomly selecting the same beach section for three consecutive days is about $0.09^3 = 0.0007$. However, we found 43 of 79 detections (0.54) were made on the same section of beach (Table 2). The UTM coordinates showed that most individuals moved about 4–6 km during stopover, traveling about 2–3 km each way as they moved out and back with the tide. This pattern of movement was confirmed by our observations of flocks on the beach and by tracking six individuals in those flocks through tide cycles. In all cases, the flocks and radio-marked sandpipers followed the tide on the same beach section. The maximum straight-line distance between detections of an individual was 20 km. In 1995, migrants that arrived late in the migration (4–12 May) moved slightly but significantly farther than individuals present early in the migration (26–30 April); 21 detections were made on the same or adjacent beach and two on more distant beaches among early migrants versus 12 and 6 detections, respectively, among late migrants ($\chi^2 = 3.9$, $df = 1$, $P = 0.049$). We had too few data for late migrants for a comparison in 1992.

DISCUSSION

At least some shorebirds return to the same beach on successive migrations, and during successive breeding and nonbreeding seasons (reviewed by Evans and Townshend 1988, Smith and Houghton 1984, Harrington et al. 1988, Pfister et al. 1998, this study). Individual Western Sandpipers in San Francisco Bay and Dunlins (*Calidris alpina*) on the Fraser River estuary held small winter home ranges and seldom mixed with other sandpipers (Warnock and Takekawa 1995, Shepherd 2001). Our study extends their conclusion to include a stopover site on spring migration. In addition, our study is among the first to examine within-site affinity at a stopover site of any shorebird on migration. Van Gils and Piersma (1999) showed that Red Knots (*C. canutus*) traveled a mean of about 20 km during a tidal cycle in the Dutch Wadden Sea during southward migration. Our study showed that individuals traveled less widely while on the Fraser River delta, with most birds moving no farther than a few kilometers over successive days. However, we do not

know if they wandered briefly before we first detected them.

The characteristic pattern of use by individual Western Sandpipers was to follow the tide down and up the beaches through a tidal cycle. Birds seldom settled in nearby fields during high tide, choosing instead to roost along the shore or fly offshore in large flocks. Although flocks used all exposed beach sections on the delta, hundreds of thousands of individuals massed on Roberts Bank during late April and early May. Fewer than 10,000 shorebirds were present on Roberts Bank from 16–24 April 1995. The numbers suddenly increased to about 70,000 on 25 April and to 350,000–500,000 between 26 and 30 April. Fewer than 100,000 were present on 1 and 3 May. At the same time, flocks of hundreds or a few thousand were present on several of the remaining beach sections. These observations led us to believe that sandpipers would follow each other to new locations between successive high tides. We were surprised to discover that they instead returned to the same section of beach on successive low tides.

We believe the reason for the strong affinity to particular beaches by Western Sandpipers was the experience they gained on the previous low tide. The risk of being caught by falcons might be too great to move from a familiar to an unfamiliar location (Ydenberg et al. 2002). The main predators of sandpipers on the Fraser River delta are Peregrine Falcons (*Falco peregrinus*) and Merlins (*F. columbarius*) that hunt mostly by surprise (Dekker 1995, 1998; Butler 1999). The sandpipers clearly were alarmed by the presence of falcons and quickly took evasive flight action. Thousands formed into large flocks over the ocean where they were pursued by falcons. Similar over-ocean flocking has been reported among Dunlins in the presence of falcons in our study area and in Europe (Dekker 1998, Hötter 2000).

Sutherland et al. (2000) suggested that Western Sandpipers might select habitats that are most suited to their bill morphology and dietary preferences. However, Lissimore et al. (1999) found no differences in culmen lengths in Western Sandpipers between the estuarine mudflats on the Fraser River estuary and a nearby lagoon on Sidney Island. However, they did find significant and consistent differ-

ences in body mass. This suggests that body mass might be a more important factor than structural size in site choice by birds at stopover sites (Van Gils and Piersma 1999, Moore and Aborn 2000).

A conservation message arising from our study is that the beaches of the entire Fraser River delta are important to shorebirds. They used all the beaches during the entire migration and individuals mostly did not move to other beaches once they had settled. Western Sandpipers were rarely seen or heard in nearby farm fields, which are used by Dunlins and Black-bellied Plovers (*Pluvialis squatarola*) during winter and spring (Butler 1999). These results suggest that Western Sandpipers have strong affinities for particular beaches on the Fraser River delta and that these mudflats are irreplaceable.

ACKNOWLEDGMENTS

We thank C. Iverson, S. Warnock, and N. Warnock for supplying and attaching radio transmitters to sandpipers in California, which allowed us the opportunity to conduct this study. S. Boyd, S. Freeman, and T. Sullivan assisted us in the field. D. McCullough assisted with GIS programming and P. Whitehead prepared the figures. Funding was supplied by the Canadian Wildlife Service and the Centre for Wildlife Ecology at Simon Fraser Univ. Comments from two anonymous reviewers and especially B. K. Sandercock improved the manuscript.

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